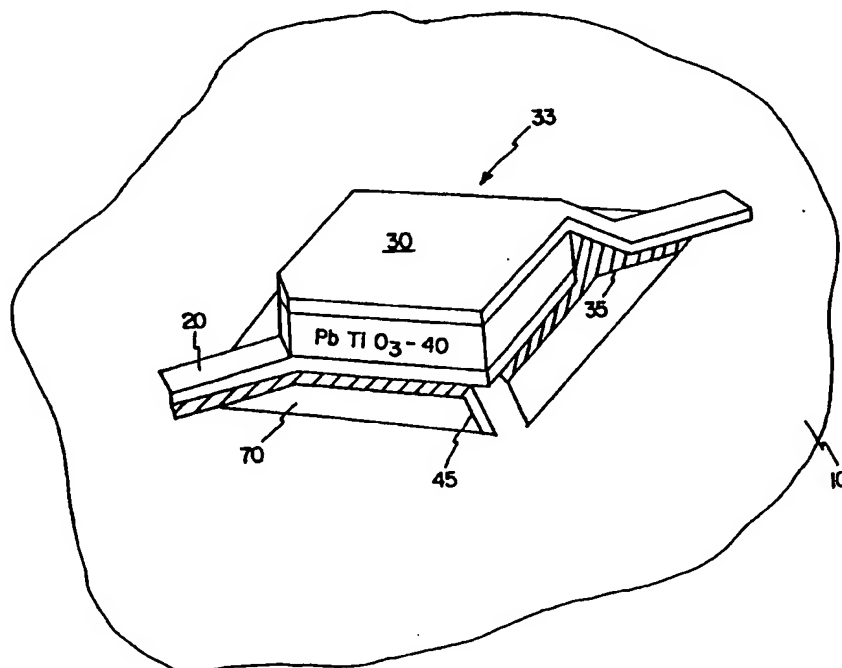




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(54) Title: THIN FILM PYROELECTRIC IMAGING ARRAY



## (57) Abstract

A thin film pyroelectric imaging array (N, M) fabricated as a Si wafer. A thin film (40) of  $\text{PbTiO}_3$  is deposited on a thermally isolated bridge (45). The bridge (45) suspends the  $\text{PbTiO}_3$  sensor (40) over a preferentially etched cavity (70) in the Si wafer (10). Improved thermal isolation increases the responsivity of the sensor (33) to incident radiation. The pyroelectric sensor (33) formed can operate effectively at room temperature.

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### THIN FILM PYROELECTRIC IMAGING ARRAY

This invention relates to a thin film pyroelectric imaging array and, more particularly, to a thin film pyroelectric imaging array constructed from coplanar electrodes on a silicon substrate utilizing a platinum electrode suspended by four bridge supports over an evacuated silicon cavity.

### BACKGROUND OF THE INVENTION

Integrated pyroelectric infrared sensors using  $\text{PbTiO}_3$  thin films are well-known in the art. Prior art radiation sensing arrays have been constructed to sense infrared radiation using a  $\text{PbTiO}_3$  thin film on a Pt-coated mica, silicon crystal or silicon membrane where the thin film was deposited by RF sputtering. Some prior art methods have employed a linear array sensor having up to 16 elements. Operating parameters of these devices have been characterized and are well known.

$\text{PbTiO}_3$  has been of interest due to its ability to operate at room temperature. Room temperature operational infrared sensors can be used for such applications as remote sensing, biomedical tomography and gas detection. Pyroelectric infrared sensors enjoy some unique advantages over other sensors such as photon sensors. Photon sensors operating in the mid to far infrared region suffer from very low operating temperature requirements which do not provide the advantage of pyroelectric detectors which can be operated at room temperature and operate well throughout the infrared region. Pyroelectric detectors have small wavelength dependence over a wide infrared range and enjoy a fast response time.  $\text{PbTiO}_3$  shows excellent pyroelectric characteristics because of its large pyroelectric coefficient and high Curie temperature.

Prior art pyroelectric detectors have been constructed from materials such as  $\text{PbTiO}_3$  ceramics and  $\text{LiTaO}_3$  single crystals. The prior art employed thin film construction techniques to manufacture planar devices. Figure 1A shows a  $\text{PbTiO}_3$  thin film device constructed with RF sputtering. The device has been fabricated as an infrared sensitive linear array which has a structure of  $\text{PbTiO}_3$  thin film on a

silicon substrate.

The structures in Figure 1A have been constructed of a thin film of  $\text{PbTiO}_3$  110, a silicon membrane 160, a silicon dioxide layer 150 and an aluminum conductor or Au-black conductor 120. Substrates were created also from a mica sheet 140 with a thickness of 20-50 microns or a silicon single crystal 140. To thin out the silicon membrane, the silicon was preferentially etched into a rectangular thin layer of about 5-20 microns thickness. Platinum/ titanium electrodes 130 with 16 elements were formed on a substrate. The  $\text{PbTiO}_3$  110 thin film has a thickness of about 2.1 microns which is deposited by RF sputtering. An aluminum or Au-black layer 120 is formed as an infrared absorbing electrode. The array sensor was electrically poled before measuring the infrared response by applying a high electric field to the  $\text{PbTiO}_3$  110 thin film at high temperature. This  $\text{PbTiO}_3$  pyroelectric infrared sensor is described in more detail in a publication of the faculty of Engineering Science, Osaka University, Japan, entitled "Integrated Pyroelectric Infrared Sensor Using  $\text{PbTiO}_3$  Thin Film", Masanori Okuyama, Hiroyuki Seto, Motohiro Kojima, Yasushi Matsui and Yoshihiro Hamakawa, Proceedings of the 14th Conference (1982 International) on Solid State Devices, Tokyo, 1982; Japanese Journal of Applied Physics, Volume 22 (1983) Supplement 22-1, pp. 465-468.

Figure 2 shows an equivalent circuit 200 of the array sensor of Okuyama, et al. The photodetection element of the array is modeled as a connection of a current source in parallel with a capacitor 210. A pyroelectric current induced under illumination fills the capacitor 210 with charge proportional to the integral of current over time. The charge is then switched through a connecting FET 220 by applying a gate pulse with a sample interval. The circuit 200 is then connected to a current amplifier for sampling. Current sampling effectively resets the sensor which is required by each sampling period.

An alternate integrated pyroelectric infrared sensor

is described in an article from the faculty of Engineering Science at Osaka University, Japan, dated December 17, 1984, found in the International Journal of Infrared and Millimeter Waves, Volume 6, No. 1, 1985 entitled "Si  
5 Monolithic Integrated Pyroelectric Infrared Sensor Made of  $\text{PbTiO}_3$  Thin Film" by Masanori Okuyama, Kohzo Ohtani, Toshiyukiueda, and Yoshihiro Hamakawa. In this sensor, the  $\text{PbTiO}_3$  thin film is sputtered onto a silicon wafer.

Referring to Figure 1B, a three dimensional drawing of  
10 the method of Okuyama, et al. 1985 is shown. In Okuyama, et al. 1985, the  $\text{PbTiO}_3$  device is now constructed as an interdigitized sensor built out of silicon cantilevers or silicon bridges. The approach described in the 1985  
Okuyama, et al. paper suffers from similar thermal problems  
15 of the device in the Okuyama, et al. 1984 paper. Such silicon structures whether solid substrate bridges or cantilevers are also poorly thermally isolated.

Therefore, it is one motivation of this invention to provide a novel  $\text{PbTiO}_3$  based pyroelectric sensor that is  
20 more sensitive to incoming infrared radiation by providing a means of more effective thermal isolation.

The invention advantageously utilizes micromachining techniques. Techniques of dynamic micromechanics on silicon have been well-known in the art. A good review of  
25 dynamic micromachining techniques can be found in an article by Curt E. Peterson in the IEEE Transactions on Electronic Devices, Vol. ED-25, No. 10, October 1978, Page 1241-1250. Silicon based dynamic micromechanics has been used for a number of applications including oil film  
30 projection systems, light valves, thin metal-coated  $\text{SiO}_2$  membranes, piezoresistive strain and pressure sensors, deflectable plated-metal cantilever beams, frequency filters, gas chromatography, and hydraulic valves utilizing silicon membranes among others. Micromechanical devices  
35 have been constructed of a thin insulated membrane attached to a silicon substrate at one end and suspended over a pit in the silicon. The pit is constructed by silicon etching

from under the deposited insulating film using a preferential etching procedure.

#### SUMMARY OF THE INVENTION

The invention provides an imaging array comprised of  
5 a thin film pyroelectric array of one or two dimensions.  
In one example, an array of silicon oxide or silicon  
nitride microbridges is prepared with a film of  
pyroelectric material such as  $\text{PbTiO}_3$  deposited on the  
silicon oxide or silicon nitride. Modulated infrared  
10 radiation incident upon the  $\text{PbTiO}_3$  causes the generation of  
a time dependent electric signal in the pyroelectric  
material, whose radiant amplitude, which varies from pixel  
to pixel, and reproduces the radiant power distribution  
incident upon the array.

15 It is an object of the invention to provide a  
pyroelectric array built on a thin layer of  $\text{PbTiO}_3$  deposited  
on a silicon oxide or silicon nitride microbridge  
structure.

It is another object of the invention to provide a  
20 pyroelectric array with high responsivity.

It is a further object of the invention to provide an  
infrared imaging system that does not depend on cryogenic  
cooling.

It is yet a further object of the invention to provide  
25 a pyroelectric imaging array that combines the thermal  
isolation of a silicon oxide or silicon nitride microbridge  
with the detection advantages of a pyroelectric material.

It is yet a further object of the invention to provide  
a pyroelectric array that does not require a bias.

30 It is yet a further object of the invention to provide  
a pyroelectric array that reduces self heating due to power  
losses.

It is a further object of the invention to provide a  
pyroelectric imaging array that minimizes  $1/F$  power noise  
35 where  $F$  is frequency.

It is still a further object of the invention to  
provide a pyroelectric imaging array that has a reduced

power requirement useful for battery powered man-portable thermal imaging viewers.

It is yet a further object of the invention to provide a pyroelectric imaging array that does not need background subtraction circuitry.

It is yet a further object of the invention to provide a pyroelectric imaging array where the electrical RC constant can be made compatible with the frame time requirement.

Other objects, features and advantages of the present invention will become apparent to those skilled in the art though the Description of the Preferred Embodiment, Claims, and drawings herein wherein like numerals refer to like elements.

#### BRIEF DESCRIPTION OF THE DRAWINGS

To illustrate the invention, a preferred embodiment of this invention will be described herein with reference to the accompanying drawings. The preferred embodiment concerns an imaging array composed of a thin film pyroelectric array of one or two dimensions.

Figure 1A shows a top and side view of the prior art sensor.

Figure 1B shows an isometric view of a prior art pyroelectric sensor.

Figure 2 shows an equivalent circuit of the prior art sensor.

Figure 3 shows an output current verses sample interval response curve sets of a prior art sensor.

Figure 4A shows a top down view of one embodiment of the invention.

Figure 4B shows a side view of the overlapping electrode of one embodiment of the invention.

Figure 4C shows an isometric view of one example of the invention using overlapping electrodes.

Figure 5A shows a top down view of an adjacent electrode embodiment of the invention.

Figure 5B shows a side view of the adjacent electrode

embodiment of the invention.

Figure 5C shows an isometric view of the adjacent electrode embodiment of the invention.

Figure 6 shows schematically a pyroelectric imaging array architecture employed in one example of the invention.

Figure 7 shows a more detailed schematic of a single pixel used in the architecture of Figure 6.

#### DESCRIPTION OF THE PREFERRED EMBODIMENT

To fully describe the preferred embodiment of the invention the theoretical performance of a pyroelectric detector will be explained. After careful review of the theory and operation of a pyroelectric detector, it will be shown that the invention markedly enhances the responsivity, noise immunity and detectivity of a pyroelectric imaging sensor.

#### Theoretical Performance of a Pyroelectric Detector

##### Responsivity

The responsivity  $R$  of a pyroelectric detector can be described by:

$$R = (\eta \omega p A r / G) (1 + \omega^2 \tau_E^2)^{-1/2} (1 + \omega^2 \tau_T^2)^{-1/2}$$

Here  $\eta$  is the fraction of incident radiant power absorbed by the sensitive element,  $\omega$  is the angular frequency,  $p$  is the pyroelectric coefficient,  $A$  is the area of the sensitive element,  $r$  is the parallel resistance,  $r_{eq}$  is the sensitive element resistance,  $r_i$  is the resistance of the input to the readout electronics,  $G$  is the appropriate thermal conductance,  $\tau_E$  is the electrical time constant, and  $\tau_T$  is the thermal time constant. The sensitive



element is the composite structure of the pyroelectric thin layer on its silicon oxide or silicon nitride microbridge.

The electrical time constant  $\tau_E$  is given by the product of the parallel resistance and the parallel capacitance of the sensitive element and readout electronics. It will be assumed that the capacitance of the sensitive element  $C_{SE}$  determines the overall capacitance. Thus the effective electrical time constant  $\tau_E$  is

$$\tau_E = RC_{SE} \quad (2)$$

The value of  $C_{SE}$  is given by

$$C_{SE} = \epsilon' \epsilon_0 A/d \quad (3)$$

where  $\epsilon'$  is the dielectric constant of the sensitive element,  $\epsilon_0$  is the permittivity of free space, and  $d$  is the thickness of the sensitive element.

The thermal time constant  $\tau_T$  is given by

$$\tau_T = H/G \quad (4)$$

where  $H$  is the thermal mass (heat capacity) of the sensitive element and  $G$  is the thermal conductance between the sensitive element and its surroundings. Thus

$$H = c'Ad \quad (5)$$

where  $c'$  is the heat capacity per unit volume of the sensitive element.

#### Noise

Consider now the sources of noise. These include Johnson noise, temperature fluctuation noise, background fluctuation noise, and amplifier noise. Since the detector is operated unbiased, there will be no  $1/f$  noise. It is

assumed that 1/f noise from the readout electronics is negligible. The Johnson noise voltage  $V_{N,SE}$

in the equivalent resistance  $r_{eq}$  is given by

$$V_{N,SE} = [4kTr_{eq}B\omega\tau_E \tan\delta (1+\omega^2\tau_E^2)^{-1}]^{1/2} \quad (6)$$

5 where  $k$  is Boltzmann's constant,  $T$  is the absolute temperature,  $B$  is the electrical bandwidth, and  $\tan\delta$  is the loss tangent of the pyroelectric element, defined as

$$\tan\delta = (\omega r_{eq} C_{SE})^{-1} = (\omega \rho_{eq} \epsilon' / \epsilon_o)^{-1} = (\omega \tau_E)^{-1} \quad (7)$$

where  $\rho_{eq}$  is the equivalent resistivity associate with  $r_{eq}$ .

10 Thus the Johnson noise in the sensitive element can also be expressed as

$$V_{N,SE} = [4kTr_{eq}B(1+\omega^2\tau_E^2)^{-1}]^{1/2} \quad (8)$$

In quadrature with the Johnson noise in the sensitive element is Johnson noise in the input resistance, given by

$$15 \quad V_{N,IR} = (4kTr_L B)^{1/2} \quad (9)$$

In pyroelectric materials there are two contributions to the loss tangent. One is the intrinsic loss resistance of the material. The other is due to "electro-thermal coupling." Prior art works have shown that for  
20 pyroelectric materials the thermal and electrical properties are uniquely interrelated. The loss tangent of pyroelectric materials due to electro-thermal coupling is

$$\tan\delta = k_T^2 \omega \tau_T (1+\omega^2\tau_T^2)^{-1} \quad (10)$$

25 where  $k_T$ , the electro-thermal coupling factor, is given by

$$k_T = [P^2 T (C' \epsilon' / \epsilon_o)^{-1}] \quad (11)$$

The contribution to Johnson noise arising from electro-thermal coupling is thus given by

$$V_{N,SE,ET} = \left[ \frac{4kT^2 r_{eq}^2 P^2 \omega^2 A^2 B}{G(1+\omega^2 \tau_E^2)(1+\omega^2 \tau_T^2)} \right]^{1/2} \quad (12)$$

5 or

$$V_{N,SE,ET} = \left[ \frac{4kGB(1+\omega^2 \tau_T^2)}{\omega^2 A^2 P^2 (1+\omega^2 \tau_E^2)} \right]^{1/2} \quad (13)$$

The contribution from electro-thermal coupling manifests itself as temperature fluctuation noise, arising from either conduction to the substrate or radiative interchange. Thus it is not necessary to postulate temperature fluctuation noise as a separate mechanism; in pyroelectric materials it is a manifestation of Johnson noise due to electro-thermal coupling.

#### 15 Detectivity

The value of the detectivity, represented by  $D^*$ , is obtained from

$$D^* = (AB)^{1/2} R (V_N)^{-1} \quad (14)$$

Under those conditions in which the intrinsic loss resistance of the sensitive element is the dominant source of Johnson noise, the value of  $D^*$ , obtained by combining equations (1), (8) and (14) is

$$D^* = \frac{\eta P A \omega [A r_{eq} (kT)^{-1} (1+\omega^2 \tau_T^2)^{-1}]^{1/2}}{2G} \quad (15)$$

25 Under those conditions in which electro-thermal coupling determines the loss, and the Johnson noise associated with it is dominant, the value of  $D^*$ , obtained

by combining equations (1), (12), (14) is

$$D^*_{ET} = [\eta^2 A (4kT^2 G)^{-1}]^{1/2} \quad (16)$$

The value of  $D^*$  given by equation (16) is the temperature fluctuation noise limit. Under those conditions in which  
5 the dominant conduction loss is radiative interchange, the value of  $G$  is given by

$$G_{RI} = 4A\eta\sigma T^3 \quad (17)$$

where  $\sigma$  is the Stephan-Boltzmann constant. In this case

$$D^*_{RI} = [\eta (16\sigma kT^5)^{-1}]^{1/2} \quad (18)$$

10 which is the well-known expression for the background limited  $D^*$  of thermal detectors. It is set by temperature fluctuation noise arising from radiative interchange between the sensitive element and the background. Its value at room temperature for  $\eta=1$  is  $1.8 \times 10^{10}$  cm  
15  $\text{Hz}^{1/2}/\text{Watt}$ .

In practice, the Johnson noise associated with the input resistance of the electronics must be included in the total noise.

Therefore, the total noise, consisting of contributions  
20 from electro-thermal coupling, the intrinsic loss resistance, and the input resistance is given by

$$V_N = \left[ \frac{4kTr_{eq}B}{(1+\omega^2\tau_E^2)} + \frac{4kGB(1+\omega^2\tau_T^2)}{\omega^2 A^2 P^2 (1+\omega^2\tau_E^2)} + 4kTr_{LB} \right]^{1/2} \quad (19)$$

In this case,  $D^*$  is determined from equations (1), (14), and (19).

## 25 Properties of $\text{PbTiO}_3$

$\text{PbTiO}_3$  has been investigated for use as a pyroelectric material both in bulk crystal and thin film forms. Representative values for a 2um thick sputtered film are as

follows:

TABLE 1  
Properties of  $\text{PbTiO}_3$

	p	$6 \times 10^{-8}$	Coul/cm <sup>2</sup> deg K
5	$\epsilon'_{PT}$	200	
	$C_{PT}$	3.2	Joules/cm <sup>3</sup> deg K
	$T_C$	470	deg C

Here  $T_C$  is the Curie temperature.

Other pyroelectric materials are suitable for use in the apparatus of the invention, examples include lithium niobate ( $\text{LiNbO}_3$ ), lithium tantalate ( $\text{LiTaO}_3$ ), barium titanate ( $\text{BaTiO}_3$ ), triglycine sulfate (TGS), zinc oxide ( $\text{ZnO}$ ) and lead zirconium titanate (PZT).

Referring now to Figure 4A, a schematic view of the sensor of the invention is shown from the one side of a silicon wafer. The invention is fabricated from a wafer of single crystal silicon upon which various processes deposit functional elements. Special features, such as thermal isolation cavities are formed by preferential etching or equivalent processes. Figure 4A shows the top view of a pyroelectric pixel indicating the configuration of the current carrying legs 20 and 30. Figure 4A shows the silicon substrate 10 which surrounds the pyroelectric pixel and also provides the supporting material for the pixel itself.

A cross section of Figure 4A is shown by Figure 4B. The silicon substrate 10 is etched away under a silicon oxide or silicon nitride to form a 45 on which the pyroelectric material has been previously deposited. The radiation sensing pixel is formed from a sandwich of conducting material and  $\text{PbTiO}_3$  supported by the structural, nonconducting legs of the microbridge 45. The conducting material of the current carrying legs 30 and 20 is isolated

from the silicon substrate by a layer of silicon dioxide or silicon nitride,  $\text{SiO}_2$ , or silicon nitride,  $\text{Si}_3\text{N}_4$ . The current carrying leg 30 forms one plate of the capacitor and can be seen in Figure 4A as the large diamond in the center. The conducting material of the opposite current  
5 carrying leg 20 forms the other plate of the capacitor, part of which is shown on the left side and part of which is obscured by the diamond in the center. The cavity 70 beneath the pyroelectric pixel physically isolates the  
10 pixel from the silicon substrate.

Figure 4C shows an isometric view of one example of the pyroelectric pixel 33 of the invention. The opposing electrode configuration of the invention is illustrated wherein the  $\text{PbTiO}_3$  is sandwiched between the Pt electrode  
15 pair. The thermally isolated microbridge can be seen suspended over cavity 70. Current carrying legs 20 and 30 can be clearly viewed as forming a capacitive structure with the  $\text{PbTiO}_3$  40. The support legs 45 are providing  
20 mechanical support as well as affording good thermal isolation from the silicon substrate 10. Absorbed infrared radiation is sensed by the  $\text{PbTiO}_3$ , the voltage difference across the leads 30 and 20 being proportional to the amount of absorbed radiation.

Referring now to Figure 5A, the schematic view of  
25 the sensor is shown from one side of a silicon substrate. Figure 5A shows an alternative top view of the pyroelectric pixel indicating the configuration of the current carrying legs 20 and 30. Figure 5A differs from Figure 4A in that the current carrying electrode 30 is no longer electrically  
30 connected to the first plate of the capacitor numbered at 25 in Figure 5A.

Figure 5B shows a cross section of a pyroelectric detector forming an alternate embodiment pyroelectric  
35 pixel. The  $\text{PbTiO}_3$  40 is suspended by a silicon dioxide or silicon nitride microbridge over cavity 70. The  $\text{PbTiO}_3$  sensing element is sandwiched between the current carrying legs 20 and 30 and the free plate 25. The free plate 25,

along with the adjacent electrodes 20 and 30, enable a more easily fabricated structure. The embodiment of the invention also provides an effective means of thermally isolating the  $\text{PbTiO}_3$  sensing element from the silicon substrate.

Figure 5C shows an isometric view of the pyroelectric imaging sensor of this alternate embodiment of the invention. The isolated sensor can be seen suspended over cavity 70. Current carrying legs 20 and 30 can be clearly seen, as in the alternate embodiment, as forming a sandwich with the  $\text{PbTiO}_3$  40 and an isolated conducting layer forming an alternate capacitor plate 25. The supporting legs 45 are providing mechanical support as well as providing good thermal isolation by separating the  $\text{PbTiO}_3$  sensor from the silicon substrate. Absorbed radiation is sensed by the  $\text{PbTiO}_3$  by a voltage difference across leads 30 and 20 proportional to incident radiation.

Now referring to Figure 6 which shows the arrangement of rows and columns of the  $\text{PbTiO}_3$  readout electronics. Each pixel 701 is represented by a square. The array is arranged in an M by N row and column fashion. A mechanical shutter 704 move in the direction of motion indicated by arrow 706. The mechanical shutter 704 selectively shades each of the N rows of M columns as it progresses along the array. Thus pixels 701 are prevented from sensing incident radiation when covered by the shutter 704. The data output pads 708 are used to send information from the array to the system using the array. Row select line 710 selects one of the N rows.

Now referring to Figure 7 which shows the details within each pixel 701, enclosed by the dotted line. The  $\text{PbTiO}_3$  pyroelectric detector is represented by the 2pF capacitor 801. The remaining devices are deposited or constructed either underneath or alongside in the silicon 10. This includes 3 FET's and a 0.1 pF capacitor. The 0.1 pF capacitor 803 can also be made of  $\text{PbTiO}_3$  in which case it

is shielded from any incident thermal radiation. In use each pixel 701 is scanned sequentially from left to right in a selected row. Then from left to right in the adjacent row immediately below and so on. The shutter is  
5 synchronized to the vertical scanning speed.

In one example embodiment of the invention the FET's of the apparatus of the invention are 25 microns wide and 50 microns long. Those skilled in the art will recognize that it is desirable to have the electronics beneath the  
10 microbridge structure in which case the use of a "sacrificial layer" is required in processing the array. In an alternative embodiment of the invention, the electronics can be in the silicon substrate alongside the microbridge. If the electronics are constructed alongside  
15 the microbridge the area of each pixel is then approximately doubled, however the sensitive part on the microbridge remains the same.

This invention has been described herein in considerable detail in order to comply with the Patent  
20 Statutes and to provide those skilled in the art with the information needed to apply the novel principles and to construct and use such specialized components as are required. However, it is to be understood that the invention can be carried out by specifically different  
25 equipment and devices, and that various modifications, both as to the equipment details and operating procedures, can be accomplished without departing from the scope of the invention itself.

What is claimed is:



## CLAIMS

1. A radiation sensor comprising:
  - (a) a substrate (10) having opposing flat surfaces wherein one surface has a cavity (70);
  - 5 (b) a microbridge (45) suspended over the cavity (70) comprised of a material selected from the group consisting of silicon oxide and silicon nitride; and
  - (c) a pyroelectric thin film pixel (40) deposited upon the microbridge (45) having first and second
  - 10 electrodes (30, 20).
2. The radiation sensor of claim 1 wherein the substrate (10) comprises a single crystal from the group consisting of silicon and gallium arsenide.
3. The radiation sensor of claim 1 wherein the microbridge
- 15 (45) is thermally isolated.
4. The radiation sensor of claim 1 wherein the microbridge (45) is supported by a plurality of support members attached to, and extending from, the substrate (10) and attached to the microbridge (45) to substantially thermally
- 20 isolate the microbridge (45) from the substrate (10).
5. The radiation sensor of claim 4 wherein the microbridge (45) is rectangular and wherein there are at least two support members extending to the corners of the microbridge (45) from the substrate (10).
- 25 6. The radiation sensor of claim 1 wherein the pyroelectric material comprises a material from the group consisting of  $\text{PbTiO}_3$ ,  $\text{LiNbO}_3$ ,  $\text{LiTaO}_3$ ,  $\text{BaTiO}_3$ , TGS, ZnO and PZT.
7. The radiation sensor of claim 1 wherein the first and

second electrodes (30, 20) comprise a material from the group consisting of platinum, aluminum and gold.

8. The radiation sensor of claim 1 wherein the cavity (70) is formed by preferential etching.

5 9. The radiation sensor of claim 1 wherein the cavity (70) is formed by anisotropic etching.

10. The radiation sensor of claim 4 wherein the first and second electrodes (30, 20) are deposited each on separate support members.

10 11. A radiation sensor having a plurality of radiation sensing pixels arranged in an array (N, M) of pixels (701) having a row and column with a first pixel and a last pixel, wherein the radiation sensing pixel comprises:

15 (a) a substrate (10) having opposing flat surfaces wherein one surface has a cavity (70);

(b) a microbridge (45) suspended over the cavity (70) comprised of a material selected from the group consisting of silicon oxide and silicon nitride; and

20 (c) a pyroelectric thin film pixel (40) deposited upon the microbridge (45) having first and second electrodes (30, 20).

12. The radiation sensor of claim 11 further including a moveable shutter means (704) and readout electronics means (708) wherein each pixel (701) further comprises a means  
25 for scanning, and wherein the means for scanning scans from a first pixel to a last pixel in a selected row and the shutter means is synchronized to the scanning of each selected row.

13. The radiation sensor of claim 12 wherein the means for scanning further comprises a self closing switch.

14. The radiation sensor of claim 11 wherein the array (N, M) is a linear array.

5 15. A radiation sensor comprising:

(a) a substrate (10) having opposing flat surfaces wherein one surface has a cavity (70);

10 (b) a microbridge (45) suspended over the cavity (70) comprised of a material selected from the group consisting of silicon oxide and silicon nitride, wherein the microbridge (45) includes a plurality of support legs;

(c) a first conductive thin film electrode (30) deposited on one of the legs covering substantially half the surface of the microbridge (45);

15 (d) a second conductive thin film electrode (20) deposited on the opposing leg and covering the remaining portion of the microbridge (45);

20 (e) a thin film of pyroelectric material (40) deposited on, and substantially covering, the surface of the first and second electrodes (30, 20); and

(f) a thin film conductor (25) deposited on the surface of the pyroelectric material (40).

16. The radiation sensor of claim 15 wherein the first and second electrodes (30, 20) comprise a material from the group consisting of platinum, aluminum and gold.

17. The radiation sensor of claim 15 wherein the substrate (10) comprises a single crystal wafer comprised of a

material from the group consisting of silicon and gallium arsenide.

18. The radiation sensor of claim 15 wherein the microbridge (45) is thermally isolated.

5 19. The radiation sensor of claim 15 wherein the pyroelectric material comprises a material from the group consisting of  $\text{PbTiO}_3$ ,  $\text{LiNbO}_3$ ,  $\text{LiTaO}_3$ ,  $\text{BaTiO}_3$ , TGS, ZnO and PZT.

10 20. The radiation sensor of claim 15 wherein the cavity (70) is formed by preferential etching.

21. The radiation sensor of claim 15 wherein the cavity (70) is formed by anisotropic etching.

22. A radiation sensor having a plurality of radiation sensing pixels (701) arranged in an array of pixels (M, N) having a row (N) and column (M) with a first pixel and a last pixel, wherein the radiation sensing pixel comprises:

(a) a substrate (10) having opposing flat surfaces wherein one surface has a cavity (70);

20 (b) a microbridge (45) suspended over the cavity (70) comprised of a material selected from the group consisting of silicon oxide and silicon nitride, wherein the microbridge (45) includes a plurality of support legs;

25 (c) a first conductive thin film electrode (30) deposited on one of the legs covering substantially half the surface of the microbridge (45);

(d) a second conductive thin film electrode (20) deposited on the opposing leg and covering the

remaining portion of the microbridge (45);

(e) a thin film of pyroelectric material (40) deposited on, and substantially covering, the surface of the first and second electrodes (30, 20); and

5 (f) a thin film conductor (25) deposited on the surface of the pyroelectric material.

23. The radiation sensor of claim 22 wherein the pyroelectric material (40) comprises a material from the group consisting of  $\text{PbTiO}_3$ ,  $\text{LiNbO}_3$ ,  $\text{LiTaO}_3$ ,  $\text{BaTiO}_3$ , TGS,  $\text{ZnO}$   
10 and PZT.

24. The radiation sensor of claim 22 further including a moveable shutter means (704) and readout electronics means (708) wherein each pixel (701) further comprises a means for scanning, and wherein the means for scanning scans from  
15 a first pixel to a last pixel in a selected row (N) and the shutter means (704) is synchronized to the scanning of each selected row (N).

25. The radiation sensor of claim 23 wherein the means for scanning further comprises a self closing switch.

20 26. The radiation sensor of claim 23 wherein the array (M, N) is a linear array.

27. A radiation sensor comprising:

(a) a substrate (10) having opposing flat surfaces wherein one surface has a cavity (70);

25 (b) a microbridge (45) suspended over the cavity (70) comprised of a material selected from the group consisting of silicon oxide and silicon nitride, wherein the microbridge (45) includes a plurality of

support legs;

(c) a first conductive thin film electrode (30) deposited on one of the legs and substantially covering the surface of the microbridge (45);

5 (d) a thin film of pyroelectric material (40) deposited on, and substantially covering, the first conductive thin film (30); and

(e) a second conductive thin film electrode (20) deposited on the opposing leg and substantially  
10 covering the thin film of pyroelectric material.

28. The radiation sensor of claim 27 wherein the first and second electrodes (30, 20) comprise a material from the group consisting of platinum, aluminum and gold.

29. The radiation sensor of claim 27 wherein the substrate  
15 (10) comprises a single crystal wafer comprised of a material from the group consisting of silicon and gallium arsenide.

30. The radiation sensor of claim 27 wherein the microbridge (45) is thermally isolated.

20 31. The radiation sensor of claim 27 wherein the pyroelectric material (40) comprises a material from the group consisting of  $\text{PbTiO}_3$ ,  $\text{LiNbO}_3$ ,  $\text{LiTaO}_3$ ,  $\text{BaTiO}_3$ , TGS, ZnO and PZT.

32. The radiation sensor of claim 27 wherein the cavity  
25 (70) is formed by preferential etching.

33. The radiation sensor of claim 27 wherein the cavity (70) is formed by anisotropic etching.

34. A radiation sensor having a plurality of radiation

sensing pixels (701) arranged in an array of pixels (N, M) having a row and column with a first pixel and a last pixel, wherein the radiation sensing pixel comprises:

- 5 (a) a substrate (10) having opposing flat surfaces wherein one surface has a cavity (70);
  - (b) a microbridge (45) suspended over the cavity (70) comprised of a material selected from the group consisting of silicon oxide and silicon nitride, wherein the microbridge (45) includes a plurality of  
10 support legs;
  - (c) a first conductive thin film electrode (30) deposited on one of the legs and substantially covering the surface of the microbridge (45);
  - (d) a thin film of pyroelectric material (40)  
15 deposited on, and substantially covering, the first conductive thin film; and
  - (e) a second conductive thin film electrode (20) deposited on the opposing leg and substantially covering the thin film of pyroelectric material.
- 20 35. The radiation sensor of claim 34 wherein the pyroelectric material (40) comprises a material from the group consisting of  $\text{PbTiO}_3$ ,  $\text{LiNbO}_3$ ,  $\text{LiTaO}_3$ ,  $\text{BaTiO}_3$ , TGS,  $\text{ZnO}$  and PZT.
36. The radiation sensor of claim 34 further including a  
25 moveable shutter means (704) and readout electronics means (708) wherein each pixel (701) further comprises a means for scanning, and wherein the means for scanning scans from a first pixel to a last pixel in a selected row (N) and the

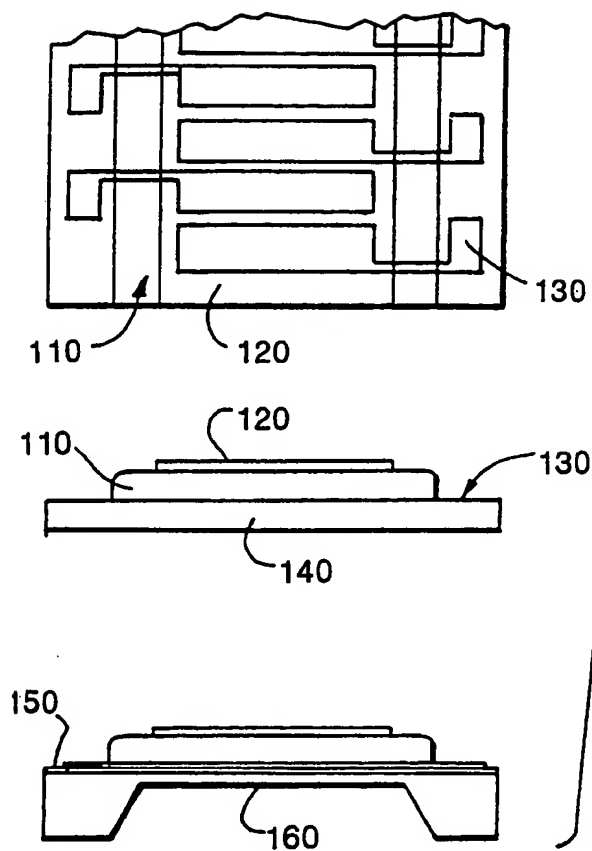
shutter means is synchronized to the scanning of each selected row.

37. The radiation sensor of claim 34 wherein the means for scanning further comprises a self closing switch.

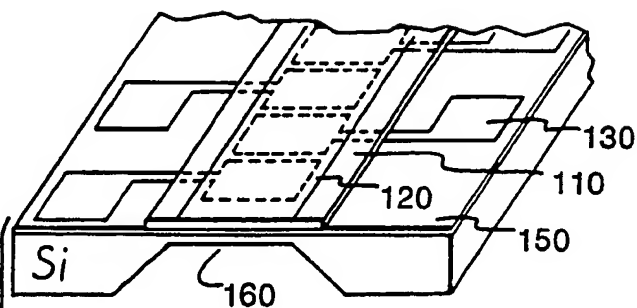
- 5 38. The radiation sensor of claim 34 wherein the array (N, M) is a linear array.



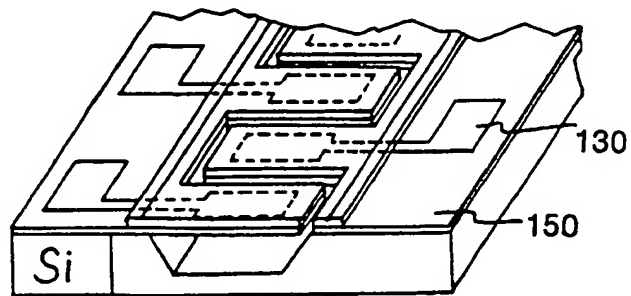
1/10



*Fig. 1A*  
PRIOR ART



*Fig. 1B*  
PRIOR ART



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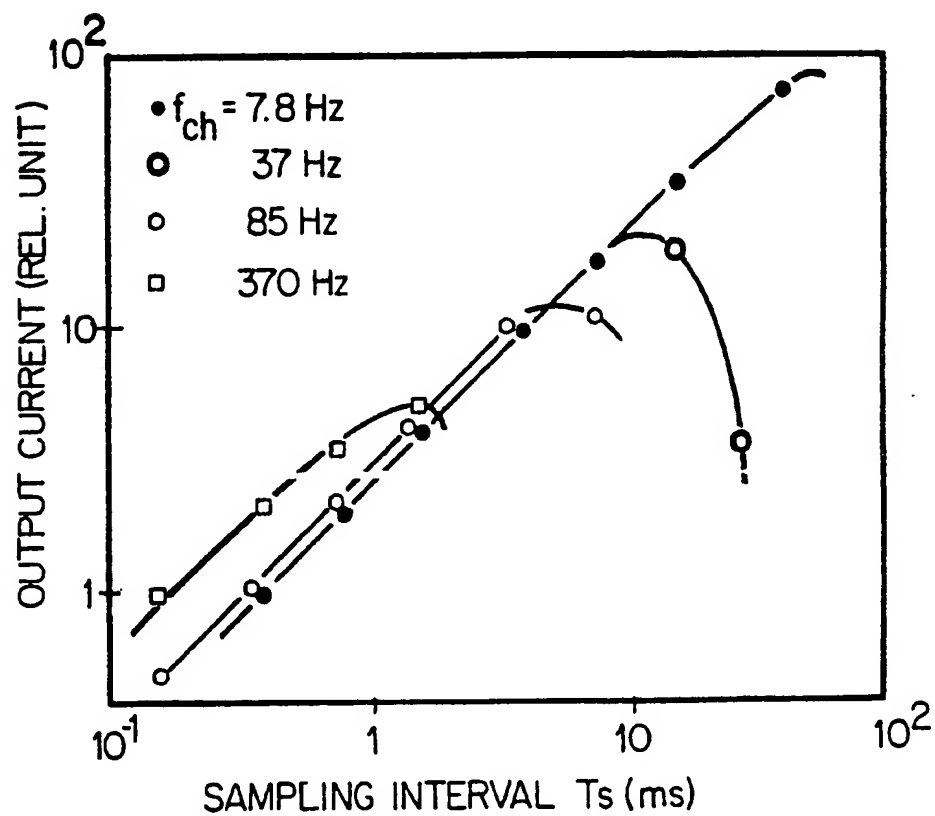
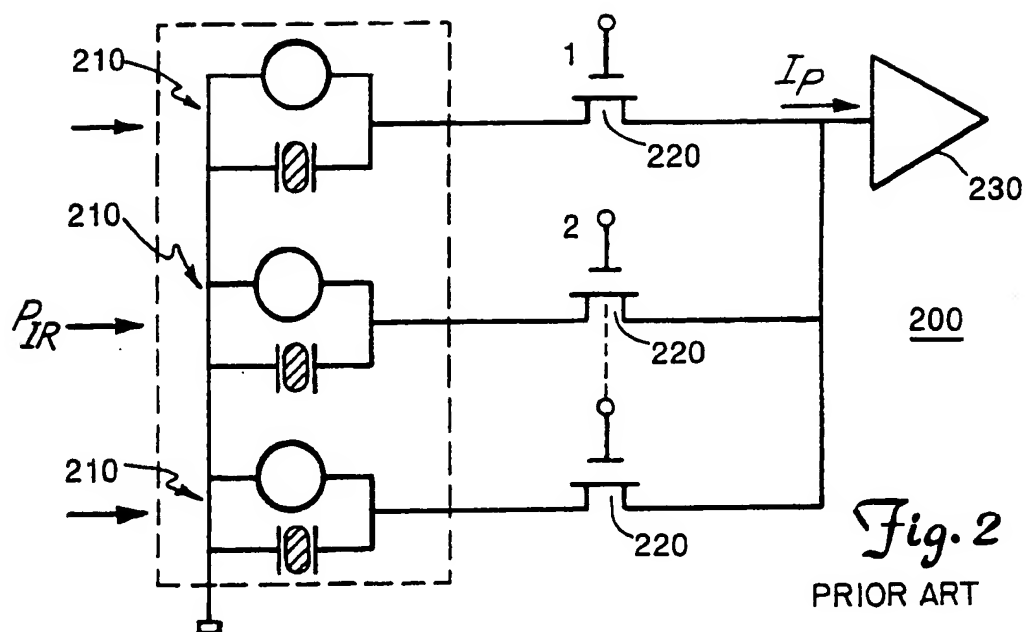
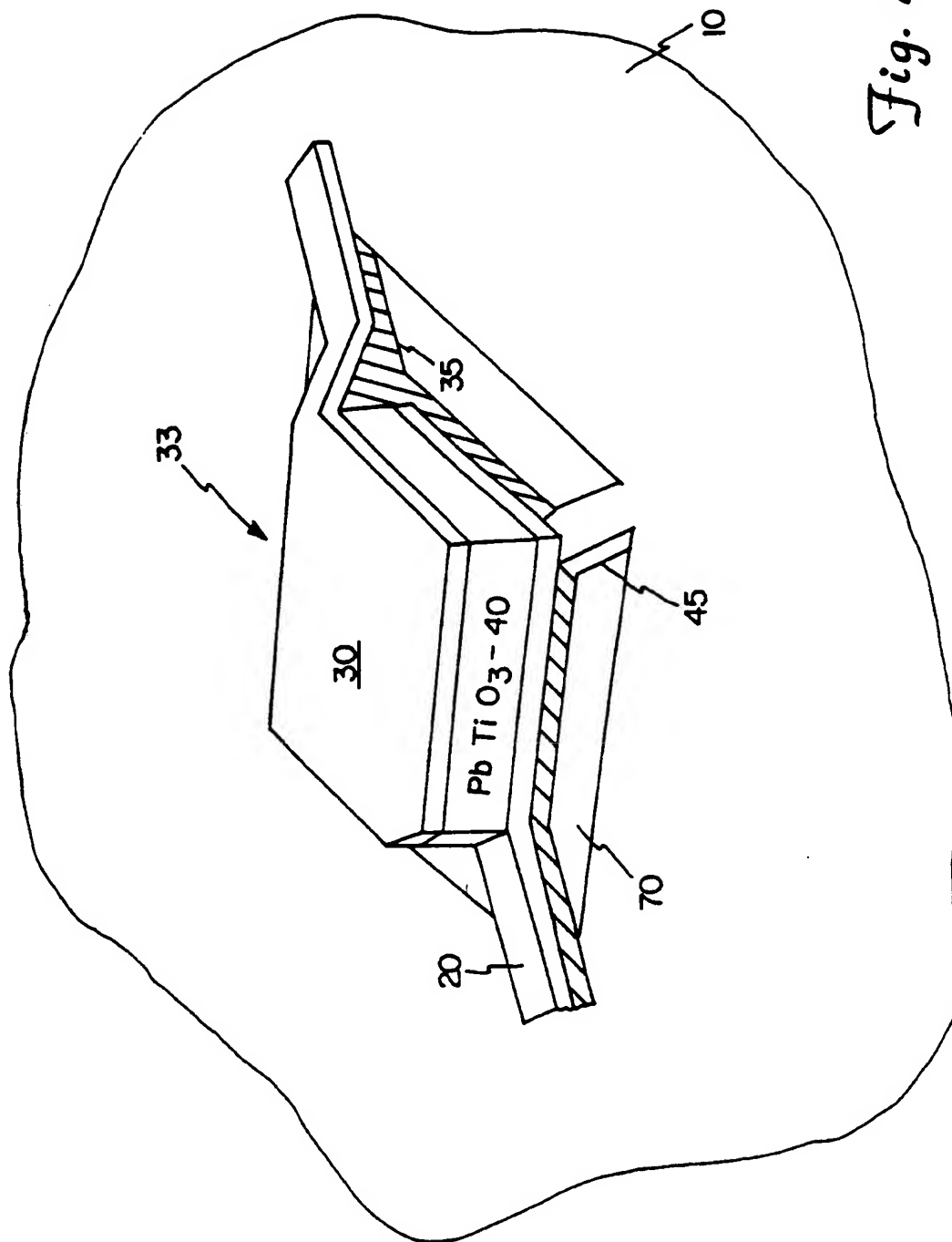


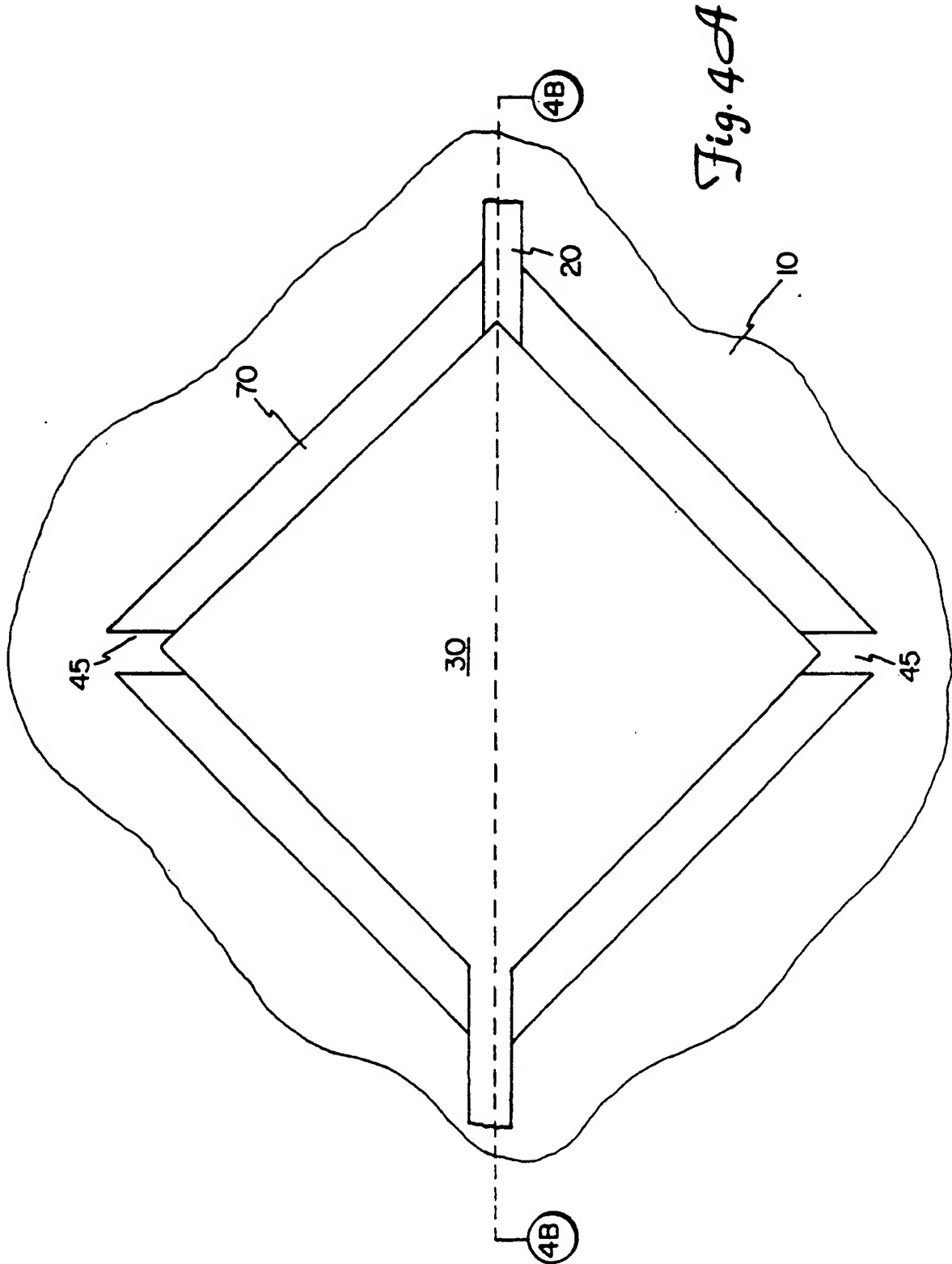
Fig. 3  
PRIOR ART

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Fig. 4



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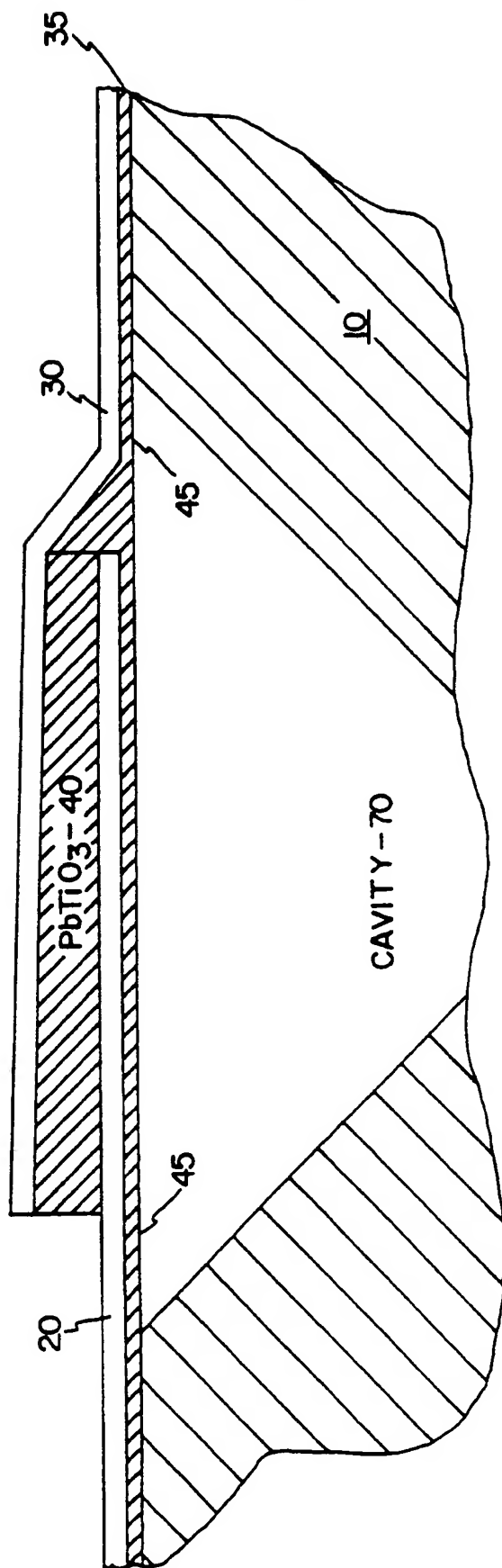


Fig. 4B

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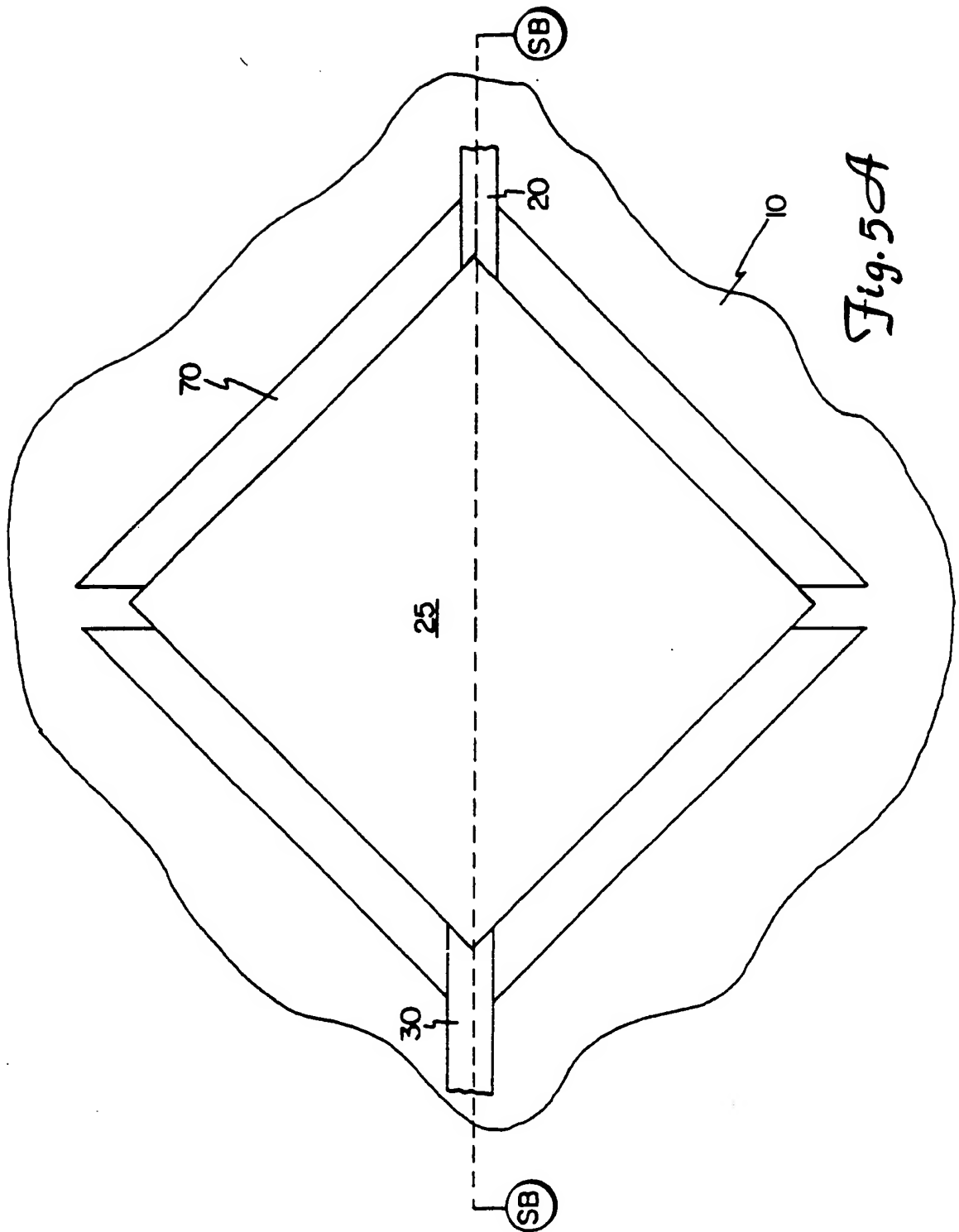


Fig. 5A

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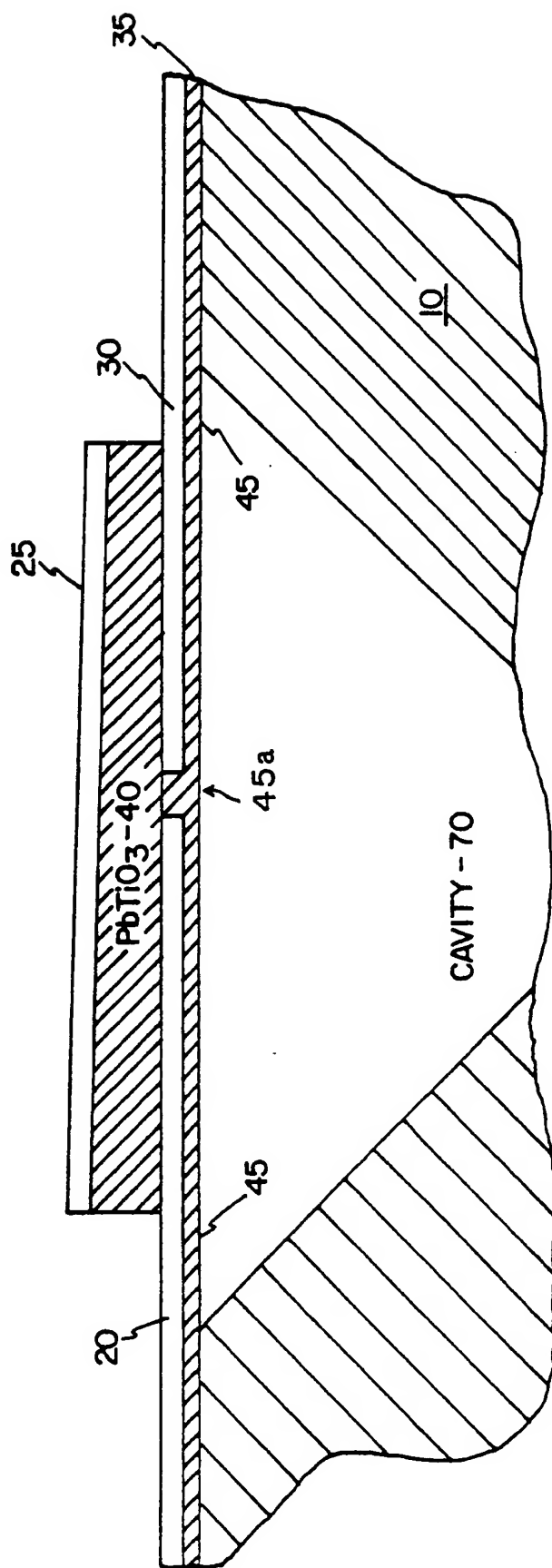


Fig. 5B

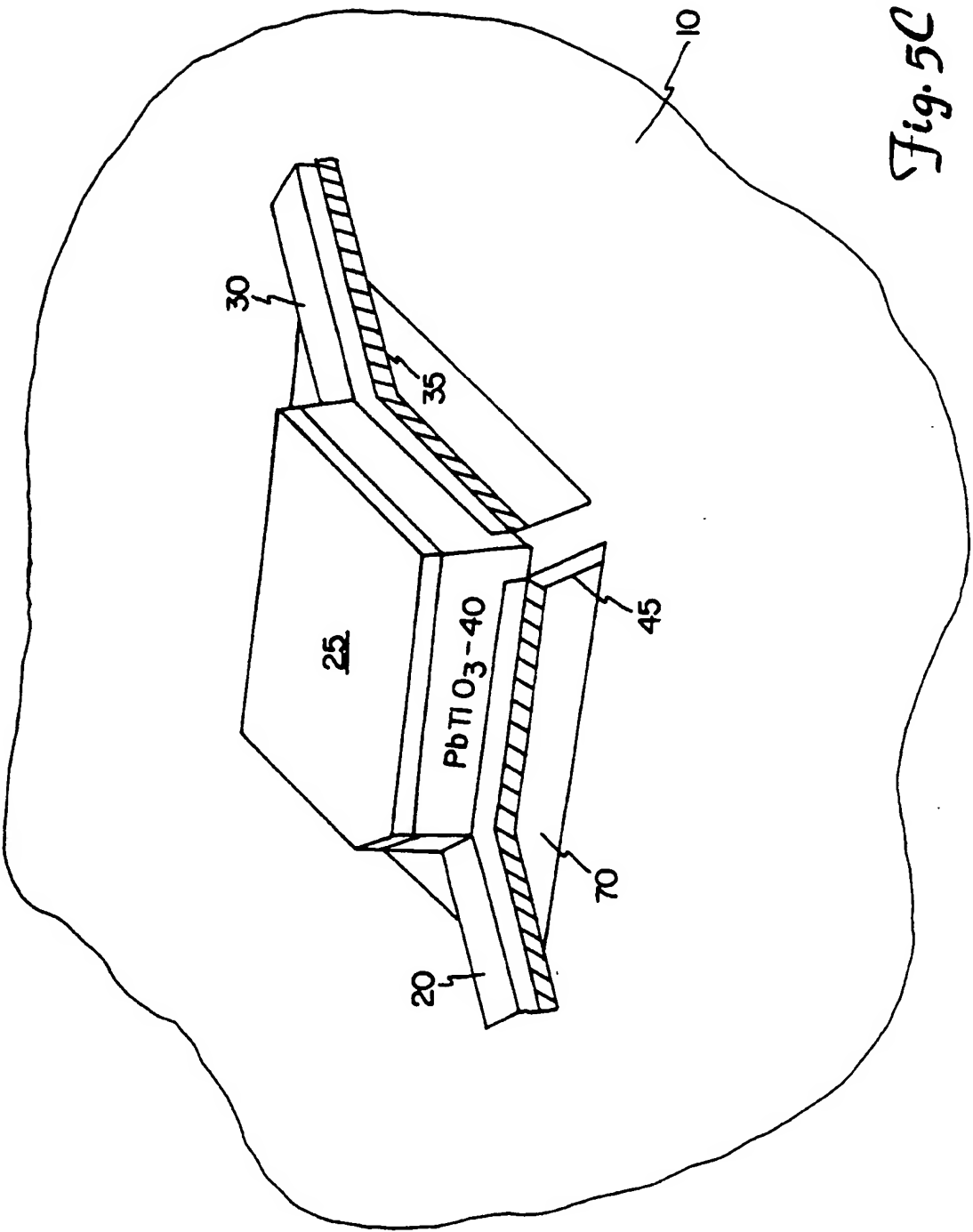


Fig. 5C



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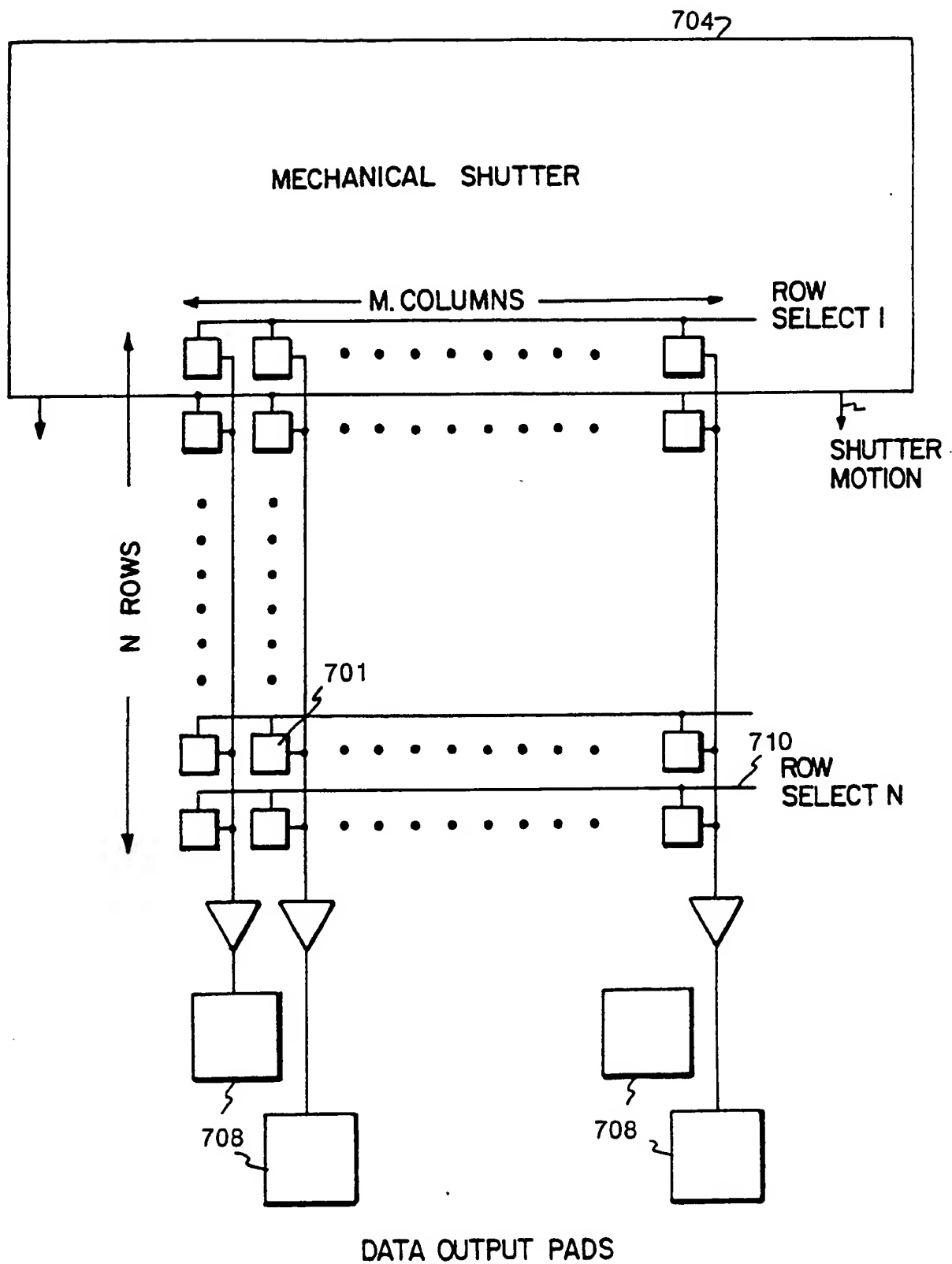


Fig. 6

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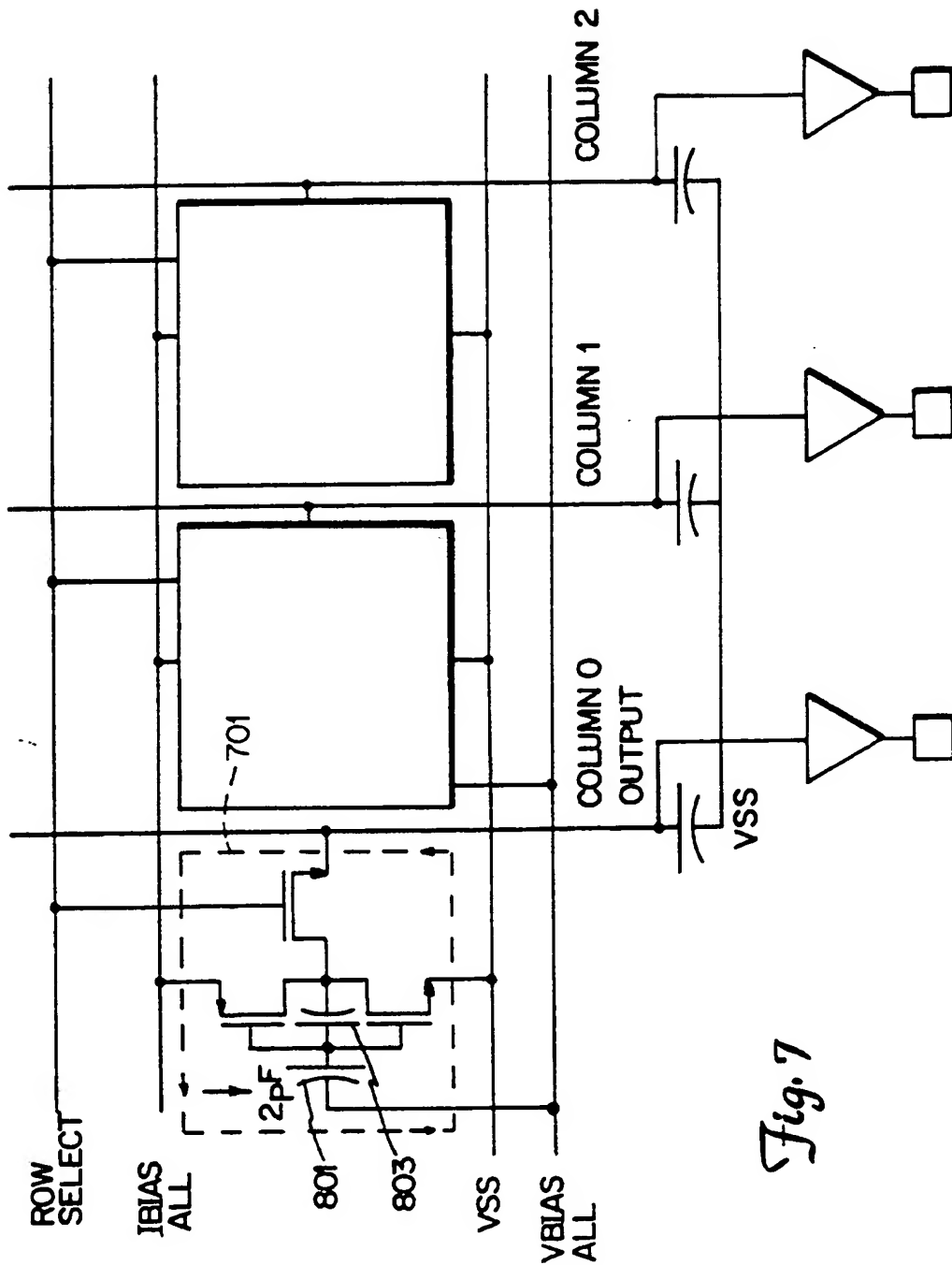


Fig. 7

SUBSTITUTE SHEET

## INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 92/09537

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (if several classification symbols apply, indicate all) <sup>6</sup>		
According to International Patent Classification (IPC) or to both National Classification and IPC		
Int.Cl. 5 G01J5/34; H01L27/16		
<b>II. FIELDS SEARCHED</b>		
Minimum Documentation Searched <sup>7</sup>		
Classification System	Classification Symbols	
Int.Cl. 5	G01J ; H01L	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched <sup>8</sup>		
<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT<sup>9</sup></b>		
Category <sup>10</sup>	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>
Y	WO,A,9 116 607 (COMMONWEALTH OF AUSTRALIA, THE SECRETARY OF DEFENCE) 31 October 1991 see the whole document	1-11, 15-21, 27-33
A	---	22,34
Y	PATENT ABSTRACTS OF JAPAN vol. 11, no. 22 (P-538)21 January 1987 & JP,A,61 195 318 ( MATSUSHITA ELECTRIC IND COMPANY LTD ) 29 August 1986 see abstract	1-11, 15-21, 27-33
A	---	23,35
A	EP,A,0 354 369 (TEXAS INSTRUMENTS INCORPORATED) 14 February 1990 see the whole document	12,24,36
	---	-/--
<sup>10</sup> Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. "&" document member of the same patent family		
<b>IV. CERTIFICATION</b>		
Date of the Actual Completion of the International Search		Date of Mailing of this International Search Report
19 FEBRUARY 1993		05. 03. 93
International Searching Authority		Signature of Authorized Officer
EUROPEAN PATENT OFFICE		LINA F.

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		Relevant to Claim No.
Category *	Citation of Document, with indication, where appropriate, of the relevant passages	
A	PATENT ABSTRACTS OF JAPAN vol. 9, no. 273 (P-401)30 October 1985 & JP,A,60 119 426 ( MURATA SEISAKUSHO ) 26 June 1985  see abstract	1,6,11, 15,19, 22,23, 27,31, 34,35
A	PATENT ABSTRACTS OF JAPAN vol. 10, no. 380 (P-528)19 December 1986 & JP,A,61 170 626 ( MATSUSHITA ELECTRIC IND CO LTD ) 1 August 1986 see abstract	1,11,15, 22,27,34
A	GB,A,2 200 246 (THE PLESSEY COMPANY PLC) 27 July 1988  see the whole document	11,12, 22,24, 34,36

**ANNEX TO THE INTERNATIONAL SEARCH REPORT  
ON INTERNATIONAL PATENT APPLICATION NO.**

US 9209537  
SA 67123

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.  
The members are as contained in the European Patent Office EDP file on  
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		EP-A- 0526551	10-02-93
EP-A-0354369	14-02-90	JP-A- 2196929	03-08-90
		US-A- 5021663	04-06-91
GB-A-2200246	27-07-88	DE-A- 3644882	17-11-88
		FR-A- 2624603	16-06-89
		NL-T- 8615006	01-08-88
		SE-B- 466571	02-03-92
		SE-A- 8702531	05-05-88

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